AL-TR-1991-0094

DTIC ELECTE S C D

AD-A241 914

ARMSTRONG LABORATORY

TESTING AND EVALUATION OF THE VANNER ELECTRICAL INVERTERS, MODELS 24-1500 AND SP 00112

Thomas E. Philbeck, Jr., Master Sergeant, USAF
Philip J. Preen, Second Lieutenant, USAF, BSC

CREW SYSTEMS DIRECTORATE
Brooks Air Force Base, TX 78235-5000

October 1991

Final Report for Period October 1990 – January 1991

Approved for public release, distribution is unlimited.

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235-5000

NOTICES

This report has been reviewed and is approved for publication.

Richard J. Knecht

RICHARD J. KNECHT, Lt Colonel, USAF, NC
Project Scientist

Roger L. Stork

ROGER L. STORK, Colonel, USAF, BSC
Chief, Systems Research Branch

RMiller

RICHARD L. MILLER, Ph. D.
Chief, Crew Technology Division

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
October 1991

3. REPORT TYPE AND DATES COVERED
Final - October 1990 to January 1991

4. TITLE AND SUBTITLE
Testing and Evaluation of the Vanner Electrical Inverters, Models 24-1500 and SP 00112

5. FUNDING NUMBERS
PE - 62202F
PR - 7930
TA - 16
WU - 12

6. AUTHOR(S)
Thomas E. Philbeck Jr., and Philip J. Preen

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Armstrong Laboratory
Crew Systems Directorate
Brooks Air Force Base TX 78235-5000

8. PERFORMING ORGANIZATION REPORT NUMBER
AL-TR-1991-0094

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
The United States Air Force Military Airlift Command (MAC) provides aeromedical airlift for Department of Defense personnel. Two aircraft, the C-130 and C-141, are primarily used for the transport of cargo, but may also be configured for aeromedical use. Neither aircraft have 110-120 volt alternating current (VAC)/60 Hz power required for medical equipment items. Inverters, manufactured by Vanner Incorporated of Hilliard OH, were selected to provide the needed power. Initially a Model 24-1500, and later a Model SP 00112 were submitted to the Armstrong Laboratory's Aeromedical Research Function at Brooks AFB TX, for testing and evaluation. Modifications must be made to comply with MIL-STD 461, Category Ale and MIL-STD 810D. Only tested medical equipment may be operated off the Vanner. Only the 4.57 m (15 ft) 4 ga cable can be used to power the Vanner. The Vanner was fitted with a remote switch bypass plug. At least 10.2 cm (4 in.) of clearance must be provided all around the Vanner. Tiewraps must be inspected for deterioration or displacement. Provided these requirements are met, the Vanner can be an effective device to provide 120-VAC for powering some medical equipment items on C-130 and C-141 aircraft.

14. SUBJECT TERMS
Aeromedical Evacuation; Vanner; Electrical Inverter

15. NUMBER OF PAGES
24

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

TABLE OF CONTENTS

List of Figures

TESTING AND EVALUATION OF THE VANNER ELECTRICAL INVERTERS, MODELS 24-1500 AND SP 00112

BACKGROUND

The United States Air Force (USAF) Military Airlift Command (MAC) provides aeromedical airlift support for Department of Defense personnel. Two aircraft, the C-130 and C-141, are primarily used for the transport of cargo, but may also be configured for aeromedical use. Neither of these aircraft have the 110-120 volt alternating current (VAC)/60 Hz power required for most medical equipment items. Each aircraft has 115 VAC/400 Hz and 28 volt direct current (VDC) which, when modified, can be used to power the medical equipment. However, additional electrical devices must be used to modify the current power. For the 115 VAC/400 Hz current power to be used, a frequency converter must be used to step-down the frequency to 60 Hz; and for the 28 VDC to be used, an inverter must be used to change the current power to 115 VAC/60 Hz.

In the mid-1970s, MAC purchased a number of frequency converters from Unitron, Inc of Garland, Texas for powering medical equipment with 60 Hz requirements, but years of use and deterioration have reduced the available number to a level that no longer meets MAC's needs. Inverters manufactured by Vanner Incorporated of Hilliard, Ohio were selected to augment the dwindling number of converters, until a more permanent replacement could be obtained. Initially Model 24-1500, and later Model SP 00112 were submitted to the Armstrong Laboratory's Aeromedical Research Function (at the time of submission, a function of the USAF School of Aerospace Medicine), at Brooks AFB, Texas, for testing and evaluation for use on aeromedical evacuation aircraft (Fig. 1).

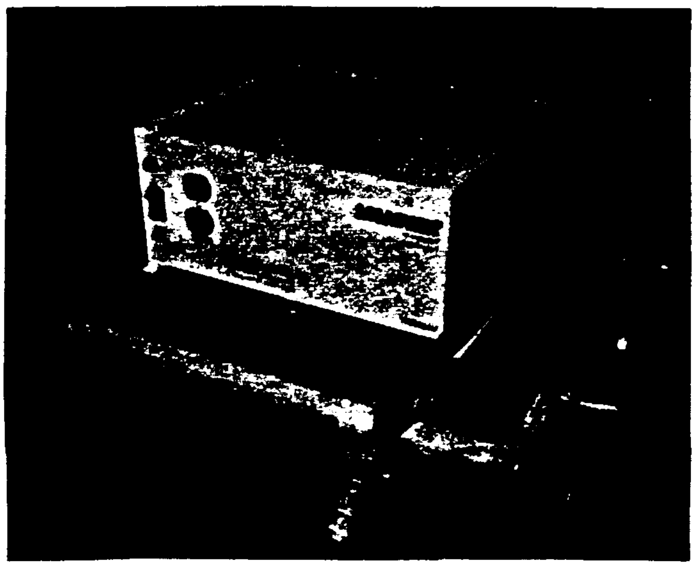

Figure 1. The Vanner Inverter model SP 00112.

DESCRIPTION

According to the Model 24-1500 Owner's Manual (1), the Vanner inverter is an electronic device which changes 20-30 VDC into 120 VAC/60 Hz with 1,500 W of power. The inverter is fan cooled and incorporates 6 basic features: (1) power available indicator light, (2) thermal cutoff, (3) factory installed direct current (DC) input cables, (4) DC input circuit breaker, (5) convenience outlets for standard alternating current (AC) loads, and (6) a microprocessor-based control board.

The Vanner inverter allows the user to easily adjust low input voltage, high input voltage, and load demand. The dimensions for the Model 24-1500 are 31.75 x 21.6 x 16.6 cm (12.5 x 8.5 x 6.5 in.), and the inverter weighs 12.7 kg (28 lb). The dimensions for the Model SP 00112 are 31.75 x 43.2 x 16.6 cm (12.5 x 17 x 6.5 in.), and the inverter weighs 25.5 kg (56 lb).

The devices employ patented circuitry and proven technology to provide a true root-mean-square (rms) quasi-sinewave form of AC power for several types of electrical loads; ***however, they are not recommended for purely inductive loads.*** The quasi-sine wave of the Vanners are produced by converting the DC input voltage into a square wave. Through the use of the transistors located in four columns on the bottom of the unit, this square wave is electrically alternated from the positive rail to the negative rail on each cycle. The alternating action of the square wave is the equivalent of AC voltage. Since this voltage power is not an actual sine wave, it is called a quasi-sine waveform. At each point the voltage rails of the waveform switch from positive to negative, there is a spike of voltage (see Fig. 2). The voltage spike is the reason some medical equipment that have inductive characteristics will not operate with the Vanners providing the AC power.

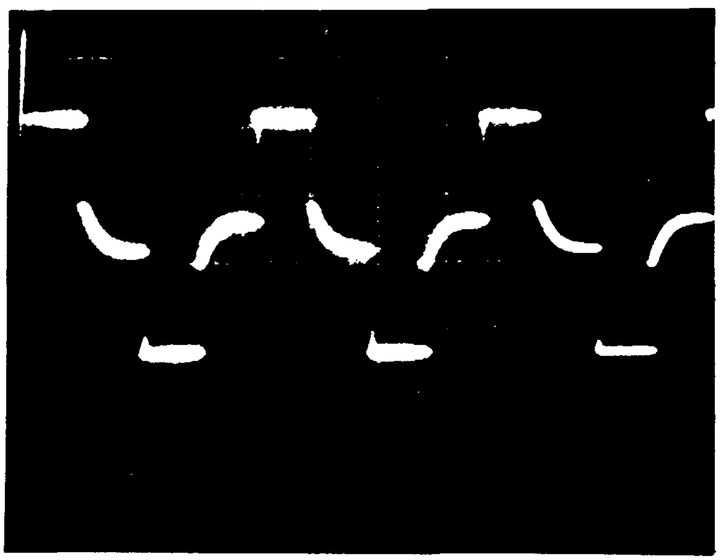

Figure 2. The Vanner Inverter quasi-sine waveform.

METHODS

Test methods and performance criteria used were derived from various military standards, nationally recognized performance guidelines (which are specified in subsequent paragraphs under each test's heading), and the manufacturer's literature. The Aeromedical Research Function Procedures Guide (2) describes testing procedures that cover safety and human factor issues regarding the equipment to be tested.

A performance check was developed verifying proper functioning of the equipment under various conditions. The device was then subjected to various tests to check its performance under anticipated operational conditions. The following tests generally involved repetition of the performance check under specified conditions: initial inspection, electromagnetic interference (EMI), vibration, environmental (encompassing hot and cold operation), altitude (encompassing hypobaric and rapid decompression testing), aircraft ground evaluation, and airborne feasibility.

Initial Inspection

Visual Inspection. The Vanners were inspected externally and internally for faulty manufacture and possible damage incurred during shipment. The inverters were disassembled and inspected for workmanship, component leakage, or damage.

Safety. The Vanners were checked to ensure the safety requirements and operating characteristics established in AFM 67-1 (3) and AFR 160-3 (4) were met. Ground resistance and current leakage measurements were made.

Operation. Operation procedures were verified with manufacturer specifications, and the performance check procedures from the protocol developed by the Aeromedical Research Function staff.

Test Setup and Performance Check

Test Setup. The standard Vanner input cables, which fit 12-V batteries, were modified with a cannon-type plug (Amphenol #MS3106F24-9P, with strain relief fitting #MS9730571016). Also, at the point where the plug was connected to the cable, test portals were installed for voltage measurement (Fig. 3).

A female adaptor identical to the outlet found on the C-130 and C-141B aircraft (Amphenol #MS3101A24-9S, with strain relief fitting #MS3057-16A) was installed on the output of a Lambda Regulated DC Power Supply Model LK 351-FM. The Lambda power supply was plugged into 120 VAC/60 Hz power and using the Cannon connectors the Vanner was plugged into the power supply, providing up to 30 VDC and 25 amps output. A Fluke Multimeter Model 8024B was plugged into the test portals to measure 28 VDC power supply output. A Tektronix Type 454 Oscilloscope

was plugged into the Vanner convenience outlet to monitor the waveform. A standard 75-W light bulb was plugged into the other outlet as a quick-check indicator of output and operation. Typically, to monitor operability of medical equipment, a Bear 33 ventilator was run off the Vanner.

Figure 3. Vanner cannon plug with voltage test portals.

Performance Check. With the power supply providing 28 VDC, the Vanner was used to power the light bulb. A special Polaroid-type oscilloscope camera, Tektronix Model C-30A, was used to record the waveform. Input voltage to the Vanner was measured and recorded.

Electromagnetic Interference

Testing was initially conducted in the Armstrong Laboratory (AL) EMI facilities, with personnel from the Maintenance Services Branch (DOJM). However, since our facility lacked an adequate power supply to provide maximum power, the Vanner was sent to the Electronic Effects and Electrical Branch, Offensive Avionics Division, Directorate of Avionics Engineering (ASD/ENACE) at Wright-Patterson AFB, Ohio for EMI testing. The purpose of EMI testing was to verify compliance with MIL-STD-461C (5). Specific tests were as follows:

Radiated Emissions (RE-02). This test measured radiated emissions generated by the devices during operation. Both narrow-band and broad-band tests were performed. Excessive emissions could interfere with aircraft navigation and communication equipment.

Conducted Emissions (CE-03). This test measured emissions generated by the devices and conducted through the aircraft power lines. This test must be performed to ensure that operating the devices using line power does not interfere with other items connected to the same power source, particularly aircraft systems.

Radiated Susceptibility (RS-02). This test determined whether the ambient electromagnetic fields (noise) encountered in flight interfered with the operation of the devices.

Conducted Susceptibility (CS-06). This test determined whether the devices could withstand predefined levels of voltage spikes on the power line.

Following initial EMI testing, the manufacturer modified the original Model 24-1500 inverter. The modified model, which was used for all remaining tests, was designated Model SP 00112. Note: Unless stated, all subsequent references to the "Vanner," "inverter," or "device" refer to the Model SP 00112.

Vibration

Using MIL-STD-810D (6) as a guide, these tests consist of random and sinusoidal waveforms on the X, Y, and Z axes, to test the Vanner's construction, durability, and performance during worst-case vibration scenarios. The Unholtz-Dickey Vibration Control Console and Vibration Table at AL/DOJM was used for the tests. The Vanner was directly bolted to a 0.63 cm (1/4 in.) metal plate. This setup was secured to the vibration table. The console and table were operated by technicians from AL/DOJM, who programmed the control console for five 15-min cycles (5-500 Hz), totaling 75 min on each axis for the sinusoidal testing; and 30 min on each axis for the random testing. Before and after the tests, visual examinations and performance checks were conducted. During the tests the Vanner and oscilloscope were under close constant observation for any changes in performance or waveform.

Environmental

These tests measured the Vanner's performance under varying temperature conditions encountered during inflight use. The Standard Environmental Systems Model TAH/15 environmental chamber was used, operated, and controlled by technicians from AL/DOJM. The Vanner was placed in the center of the environmental chamber. All input and output cables and wires were routed through a port in the chamber wall, and sealed with putty. The other components of the test setup were outside the chamber. A performance check was conducted before and after each test. The following operations describe the conditions of the environmental tests performed:

Hot Operation. The environmental chamber was set at 48.8 °C (120 °F). The Vanner was placed in the chamber for 2 h. The oscilloscope was closely monitored, and the Vanner was observed through a viewing window in the chamber door.

Cold Operation. The environmental chamber was set at 4.4 °C (40 °F). The Vanner was placed in the chamber for 2 h. The oscilloscope was closely monitored, and the Vanner was observed through a viewing window in the chamber door.

Altitude

Testing was conducted in the research chambers, operated and monitored by chamber operations personnel assigned to the Systems Research Branch of the Crew Technology Division at AL.

Hypobaric Chamber Testing. In a series of tests, the Vanner was set up inside the chamber. Pre- and post-test performance checks were conducted. The chamber was depressurized to 10,000 ft equivalent (523 mmHg total pressure), at a rate of 5,000 ft per minute. While at altitude, usually for approximately 1 h, standard performance checks were performed.

Rapid Decompression Testing. The Vanner, unpowered and without the test setup, was placed inside the small equipment rapid decompression test chamber and the chamber pressurized to an equivalent of 8,000 ft altitude. Abruptly the simulated altitude was changed to 40,000 ft over a period of 60 s. The chamber pressure was returned to ground level, the Vanner removed, and a performance check was done. The test was repeated twice with the decompressions occurring over 7 and 1 s, respectively.

Aircraft Ground Evaluation

A ground evaluation of the Vanner was conducted at Charleston AFB, SC aboard a C-141B. The evaluation was conducted by 2 biomedical research engineers, and an aircraft-qualified aeromedical research technician. With maintenance personnel providing 28 VDC power from the aircraft auxiliary power unit (APU) and engines, the Vanner's performance was evaluated using the test setup, and by operating 3 Impact Model 308M Portable Suction Units, a Bennett MA-1 Ventilator, and a Timeter Aridyne Medical Air Compressor Model 3500 off the Vanner. Also evaluated was the Vanner's output using 3 consecutive 15.2 m (50 ft) extension cords, from the Electrical Cord Accessory System (ECAS) kit, to power the medical equipment.

Follow-Up Testing at Manufacturer

Follow-up testing was conducted by a biomedical research engineer and an aeromedical research technician, at the Vanner Incorporated testing laboratory in Hilliard, Ohio, to determine specifically which medical equipment items could be powered using the Vanner as the AC power source.

Medical Equipment Items Tested.

-- Impact 308M Suction Units (x 3)

-- Bear 33 Ventilator

-- ProPaq 106 Vital Signs Monitor

-- Bard Parker Nebulizer Heater

-- Bear LS 420 Humidifier

Test Equipment Used.

-- 1/2 hp motor

-- DC Power Supply, rated at 40 VDC/250 amps

-- DC Power Supply, rated at 40 VDC/100 amps, generated by alternator to simulate aircraft power.

-- Philips PM 3323 Oscilloscope with a maximum sampling rate of 500 ms/s.

-- Watt meter box, consisting of a box with 8 100-W light bulbs and a meter to indicate wattage being drawn.

-- Amp current probe amplifier

-- Testing box, an outlet box providing access to its internal wires. All power was routed through the box, from the Vanner to the equipment items being used to test the Vanner's performance.

Test Procedures. To stay consistent throughout testing, all tests were 25 min in duration. (Due to overheating potential, the Impact Suction Pumps can only run for 27 min per h, followed by a 40-min cool-down period.) The Vanner was plugged into the power supply. The testing box was plugged into the output of the Vanner so that the drawn amps could be measured. The watt meter box was plugged into the output of the testing box. Two extension cords were connected in series and then plugged into the watt meter box. Each piece of equipment was tested on the Vanner individually. Specific tests on individual items were as follows:

-- Nebulizer Heater. Operating parameters were determined.

-- Impact Suction Units. With all 3 units operating at once, the input voltage to the Vanner was varied and the performance characteristics of the units were observed.

-- Bear 33 Ventilator. The Bear was operated concurrently with the humidifier, since there was a requirement to run them together.

All of the equipment was then tested while operating simultaneously to create a maximum load condition. The DC voltage was varied to determine the operating parameters of the Vanner.

In addition to those tests, a fully resistive load of light bulbs was used and the voltage was varied. Conversely, a purely inductive load was tested while varying the DC voltage.

The power supplied by an aircraft DC system is not pure. Since AC voltage is generated by the engines and then altered to DC voltage, there is a 400 Hz ripple associated with the power. To simulate this condition, a DC power supply generated by an alternator was used to power the Vanner. All of the equipment was once again tested as the load was varied.

Also, the equipment was powered by the Vanner through 4 Electrical Cord Assembly Set (ECAS) 115 VAC/60 Hz power cords. The power cords were connected in series, and were 7.62 m (25 ft) in length each, for a total of 30.5 m (100 ft) in length. The resistance (in ohms) and voltage were measured from an outlet at the end of the 4th cord.

Airborne Feasibility

Testing was conducted by an aeromedical research biomedical engineer and an aircraft-qualified aeromedical research technician, aboard a C-130 aeromedical evacuation training mission out of Kelly AFB, TX. The Vanner was secured to the floor under a center litter tier, and powered by the left aft 28 VDC iron lung outlet. The test equipment was secured to 2 litters placed in the tier above the Vanner. A Tektronix Model 211 portable oscilloscope was used to monitor the waveform. Aircraft voltage was monitored using the Fluke Multimeter. Three Impact 308M suction units, a Bear Model 33 ventilator, and a Bear Model LS 420 humidifier were operated off the Vanner; using power provided on the ground by the external power cart and APU, and airborne by the aircraft engines. Securing methods were also evaluated, as were set-up times and locations. Note: While an additional evaluation on the C-141B aircraft was desired, it was not possible due to nonavailability of airframes.

RESULTS

Initial Inspection

Visual Inspection. No damage or defects were noted.

Safety. Ground resistance and current leakage were acceptable.

Operation. The Vanners operated as described in the Owner's Manual.

Electromagnetic Interference

The Model 24-1500 initially failed EMI radiated and conducted tests. The conducted emissions revealed severe degradation to the 28 VDC power supply bus. Transient voltage spikes as high as 100 V at a rate of 120/second were observed. ASD/ENACE at Wright-Patterson AFB, Ohio recommended the addition of a filter as shown in Figure 4.

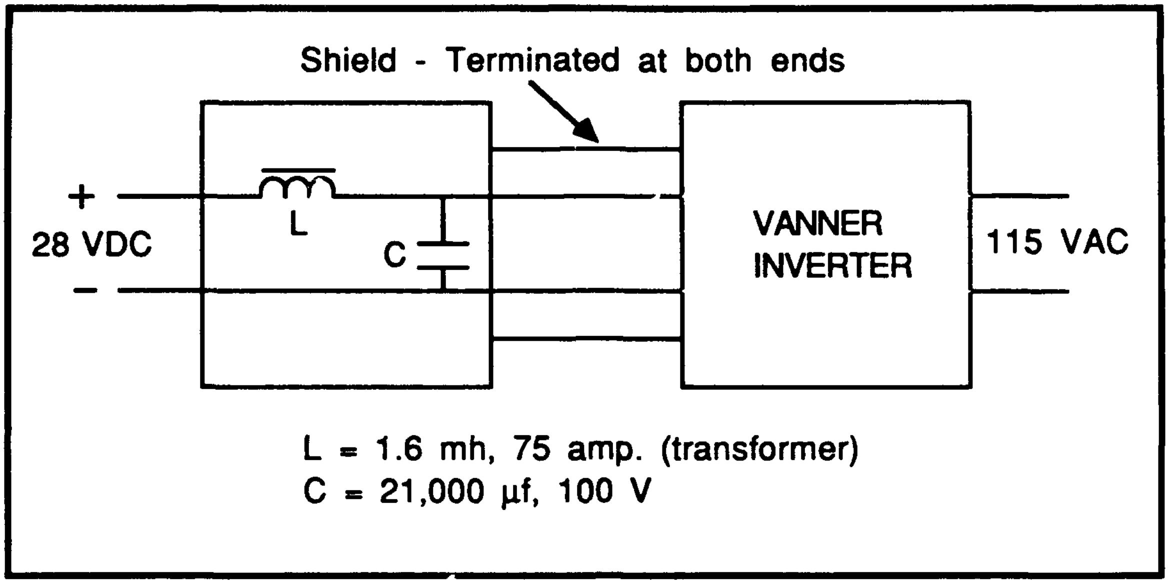

Figure 4. Vanner filter installation.

The Vanner was returned to the manufacturer for filter installation. The installation substantially increased the size and weight of the Vanner by approximately 100%; however, it did pass EMI when retested by ASD/ENACE. The modified version was designated Model SP 00112, and used for all subsequent testing and references in this report.

Vibration

At the end of the third sweep of Z-axis sinusoidal testing, a bolt securing the transformer broke. The bolt was replaced with a hardened bolt, and testing resumed. The brackets holding the transformer broke. The brackets were replaced and an additional support plate was installed. When testing resumed, flying sparks were observed from the lower front panel of the Vanner. Testing was stopped and we opened and inspected the Vanner. We noticed no damage and the Vanner continued to operate satisfactorily, so we resumed testing.

During the Y-axis sinusoidal testing, in the 29 to 67 Hz range, we noticed that voltage drawn from the DC power supply increased from 28 to 38 V; however, testing was not stopped. Sinusoidal testing was completed, and during random testing, the voltage drawn from the DC power supply reached 32 V.

At the onset of X-axis random testing, the Vanner abruptly ceased operation. Inspection revealed 2 broken capacitor support brackets. Also, a circuit board had separated from its bracket, main power cables inside the Vanner had frayed, and cable insulation had eroded due to contact with internal components. Many transistors

were also damaged. A Vanner engineer came to our facility for consultation, and hand carried the inverter back to his facility for repair and modification.

The manufacturer repaired the broken capacitor brackets and transistors, rerouted the cables, and repositioned the circuit board. Additional tie-wraps were also used to help secure components and cables. The engineer from the company personally delivered the repaired Vanner to our facility and remained on-hand for the repeat of vibration testing.

Repeat testing started with the X-axis. There were no problems encountered during sinusoidal or random testing. During Y-axis random testing, the waveform disappeared from the oscilloscope. Testing was stopped, and we found that the leads had separated from the transformer. The leads were reattached and testing resumed. After 15 min, the waveform was significantly changed. Inspection revealed the output resistor had broken free of its leads; it was reattached and reinforced. Vibration testing resumed and no further problems were encountered.

Environmental

The Vanner operated satisfactorily during hot and cold operation testing.

Altitude

Hypobaric Chamber. *The Vanner operated satisfactorily.*

Rapid Decompression. The Vanner operated satisfactorily following each decompression.

Aircraft Ground Evaluation

Only the Impact Suction devices operated satisfactorily. Operation of the Aridyne air compressor caused significant changes to the Vanner output waveform, so operation of that device was discontinued. The testing ended prematurely when the MA-1 ventilator started smoking, requiring aircraft evacuation. Inspection revealed that a burnout of the MA-1 input capacitors, designed to clean any irregularities in the incoming AC power, caused the smoking. We determined that the capacitors were not capable of functioning with power that was not a true sine-wave, such as that provided by the Vanner; and, therefore, the Vanner should not be used to power the MA-1 ventilator. The Vanner operated satisfactorily using 3 consecutive ECAS cords, totaling 22.9 m (75 ft), to provide power to the medical equipment, with no appreciable loss of power.

Follow-Up Testing at Manufacturer

After testing each piece of equipment, we determined that they would individually operate safely on the quasi-sine wave of the Vanner. When the 3 Impact Suction units were operated together, no significant change to the output waveform of the Vanner was found. When varying the voltage, we noted that under 24 V there was a noticeable diminish in the audible sound of the units, but they still operated within their operational specifications. The nebulizer heater worked as specified by the manufacturer.

When the Bear 33 and the humidifier were operated together, the humidifier quit working during the heating cycle. The output waveform of the Vanner was found to be nearly a square wave with this type of load. A capacitor and resistor were added to the test box to clean up the waveform. After further testing we determined that this modification would not keep the humidifier operational. The modification was removed and testing continued on all of the medical equipment except the humidifier. After contacting the Bear manufacturer, we determined that because of the zero sensing needs of the humidifier, it needs to have a true sine wave to run properly. The quasi-sine wave of the Vanner was not sufficient because of the voltage spikes in the waveform. We decided that testing would continue on all equipment except the humidifier. The company's engineer said they could possibly adjust the output with a future modification, allowing the use of the humidifier.

No other problems were noted. With a purely resistive load on the output, the waveform remained in the same quasi-sine waveform. With a purely inductive load, there was a distortion of the waveform. This waveform could possibly create problems in some medical equipment, as when the MA-1 ventilator was damaged during the ground evaluation on the C-141B aircraft. The company engineer advised that the future modification for the humidifier would also allow an inductive load to be run, without harm to the equipment.

When using 4 consecutive ECAS cords attached to the Vanner, the medical equipment operated satisfactorily. There was a total resistance of 0.5 ohms, which was considered satisfactory. There was a voltage drop of 6 to 9 V which resulted in no change in the performance of the equipment operating off the Vanner and ECAS cords.

In the final test conducted at the company, the medical equipment did operate without any problem when the DC power supply, generated by an alternator, was used. ***Items that were cleared for use with the Vanner were as follows: Impact 308M Suction Unit, Bear 33 Ventilator, ProPaq 106 Vital Signs Monitor, Bard Parker Nebulizer Heater.***

The company submitted a prototype of a modification which allowed the Vanner to produce an output sufficient to run an inductive load. The prototype consisted of a zero clamping electronic device which holds the quasi-sine waveform at zero for a longer period. It was designed to allow the output waveform of the Vanner to be

compatible for the zero-sensing circuitry of the humidifier. The device was evaluated during airborne feasibility testing.

Airborne Feasibility

The Impact Suction devices and the Bear 33 ventilator operated satisfactorily. In spite of the inductive load modification, the Bear humidifier did not. The device ***seemed*** to be operating satisfactorily, but when unplugged after 30 min of use to relocate within the aircraft, we noticed that the humidifier power cable was extremely hot, even near the melting point. We immediately unplugged the humidifier, while continuing testing of the other items.

The Vanner was easily secured to the floor of the aircraft using a cargo tie-down strap placed across the top, from side-to-side. The strap should not be placed front-to-back; as the part of the cover that overhangs the front and back was bent when the cargo tie-down strap was minimally tightened. The Vanner was capable of quick and easy connection to the aircraft 28 VDC system. The medical equipment could be plugged directly into the Vanner, but due to the location of the Vanner on the floor it was more practical to use extension cords from the ECAS.

REQUIREMENTS AND RECOMMENDATIONS

The following requirements and recommendations were made in an interim report to Headquarters Military Airlift Command SGON:

Requirements

-- Modifications made during the evaluation must be incorporated into production models, to pass electromagnetic interference testing, as specified in MIL-STD 461, Category A1e; and to pass vibration testing, as specified in MIL-STD 810D.

-- The Vanner output is a quasi-sinusoidal rather than a true sinusoidal waveform. Though most medical equipment should run off of this waveform, some sensitive equipment may have problems. Any medical equipment that will be operated off the Vanner must be tested in a controlled environment first. The testing can be performed by this function, or by a Medical Equipment Repair Center (MERC). ***Only the following items have been tested and may be used with the Vanner:*** Bear 33 Ventilator, which draws 1.25 amps from the Vanner. ***(The Bear humidifier may not be used.)*** ; Bard Parker nebulizer heater, which draws 1.25 amps; Impact Model 308 Suction, which draws 2.0 amps; Protocol Propaq Model 106 vital signs monitor, which draws 0.2 amps.

-- The Vanner may be effectively used if plugged into the C-130 28-V iron lung or C-141 cannon type plugs. Due to the minimal amperage input into the Vanner from the outlets, the C-130 or C-141 twist-lock outlets must not be used. Only one Vanner

may be connected to each bus. Outlet and bus locations on the C-130 are shown on Figure 5. Amperage availability on each aircraft is listed on Figure 6.

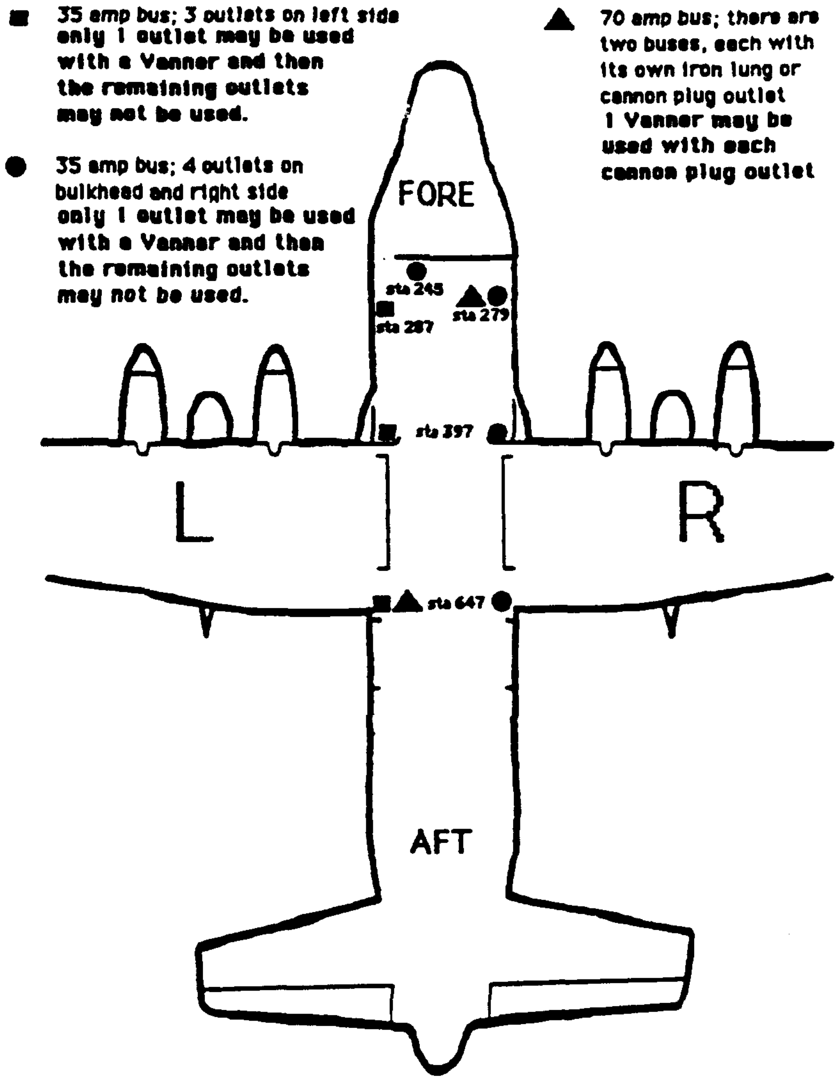

Figure 5. 28-V outlets on C-130 aircraft.

-- The 4.6 m (15 ft), 4 ga cable provided with the Vanner is the only cable that can be used between the Vanner and the aircraft 28-V outlet. ECAS cords can be used from the output of the Vanner to connect to the medical equipment.

-- Since the remote switch feature is not needed or wanted, the Vanner must be fitted with a remote switch by-pass plug. The plug can be fitted externally, but preferably internally.

-- When secured on the aircraft, at least 10.1 cm (4 in.) of clearance must be around and above the Vanner for air circulation.

VANNER 126 VOLT OUTPUT (IN AMPERES) WHEN POWERED BY AIRCRAFT 28 VDC SYSTEMS

Type of outlet	# of buses	Outlets per bus	Amps per bus	x 80% efficiency	x 28 VDC (= watts)	x 83% Vanner efficiency	÷ 120 VAC from Vanner (= amps per bus)
C-130 Iron Lung	2	1	70	56	1568	1301	10.85
C-130 Twist Lock	2	3 or 4	35	28	784	651	5.43
C-141 Cannon	2	1	70	56	1568	1301	10.85
C-141 Twist Lock	2	1	7.5	6.0	168	139	1.16

AVAILABLE AMPERAGE FROM EACH 28 VDC BUS WHEN INVERTED BY VANNER

C-130 Iron Lung	C-130 Twist Lock	C-141 Cannon	C-141 Twist Lock
10.85	5.43	10.85	1.16

AMPERAGE REQUIRED FOR A/E EQUIPMENT REQUIRING 110-120 VAC/60 HZ POWER SOURCE

Andyne Air Compressor	MA-1 Ventilator	Neonatal Transport System	Bear 33 Ventilator w/humidifier
8.5	6.7	4.2	1.5

NOTES

1. On the C-130 four Vanners may be effectively used; one off of each bus (not each outlet).

2. On the C-141B only two Vanners may be effectively used; one from each 28 VDC bus/cannon outlet. A Vanner may be used with each 28 VDC twist-lock outlet, but the output in amps is insufficient for most AE equipment.

3. The formula used to determine the amperage available from each bus using a Vanner is as follows:

Vanner output amps = amps per bus x 80% (a safety factor to allow for surges) x 28 VDC (to convert to watts) x 83% (minimum efficiency as stated by the Vanner Co.) ÷ 120 VDC (output from Vanner).

Figure 6. Amperage available from Vanner on C-130 and C-141 aircraft.

-- Tie-wraps are used throughout the Vanner to secure components and cables. Whenever maintenance is performed, any broken or displaced tie-wraps must be replaced.

Recommendations

-- The Vanner should be modified to include handles for carrying and securing.

-- The Vanner should be modified to include rubber "feet" or something similar to cushion it when secured directly to the aircraft floor.

-- Transistors located internally at the lower end of the Vanner are prone to damage. They should be frequently checked by maintenance personnel for damage.

CONCLUSION

Modifications must be made to comply with MIL-STD 461, Category A1e and MIL-STD 810D. Only tested medical equipment may be operated off the Vanner. The Vanner must not be used with the C-141B twist-lock outlets. Only the 4.6 m (15 ft) 4 ga cable can be used to power the Vanner. The Vanner must be fitted with a remote switch by-pass plug. At least 10.1 cm (4 in.) of clearance must be provided all around the Vanner. During maintenance, tie-wraps must be inspected for deterioration or displacement. Provided those requirements are met, the Vanner can be an effective device to provide 120 VAC for powering some medical equipment items on C-130 and C-141 aircraft.

ACKNOWLEDGMENTS

We thank all those who helped and advised us during the evaluation of the Vanner Inverters, particularly: Lt Col Richard Knecht, Lt Col Garye Jensen, Capt Teresa Lewis, 1Lt Rebecca Schultz, CMSgt Myron Christopher, MSgt Victor Elizondo, TSgt Louis Argus, SSgt Steve Simon, SSgt Thomas Waters, and Mr John Thompson.

REFERENCES

1. Vanner Owner's Manual, Vanner Incorporated.

2. Aeromedical Research Function Procedures Guide (Draft), Aeromedical Research Function, Armstrong Laboratory, Brooks AFB TX, 1991.

3. AFM 67-1, Volume V, Chapter 21, Medical Equipment Maintenance and Repair.

4. AFR 160-3, Electrical Safety in Medical Treatment Facilities.

5. MIL-STD 461C, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference, Category A1e.

6. MIL-STD-310D, Environmental Test Methods and Engineering Guidelines.